AD NUMBER
AD303459
CLASSIFICATION CHANGES
TO: unclassified
FROM: secret
LIMITATION CHANGES
TO: Approved for public release, distribution unlimited
FROM: Controlling Organization: British Embassy, 3100 Massachusetts Avenue, NW, Washington, DC 20008. Document partially illegible.
AUTHORITY
DSTL, AVIA 6/20567, 28 Jul 2008; DSTL, AVIA 6/20567, 28 Jul 2008

#v8

TECH. NOTE
MECH. ENG. 261

CONFIDENTIAL

TECH. NOTE
MECH. ENG. 261

[redacted]

[redacted]

REVIEW ON June 88

ROYAL AIRCRAFT ESTABLISHMENT

(FARNBOROUGH)

TECHNICAL NOTE No: MECH. ENG. 261

581560

AD 303459

CONTINUOUS-ROD WARHEAD LETHALITY TRIALS AGAINST STATIC AIRCRAFT TARGETS (RODS $\frac{1}{4}$ inch x $\frac{1}{4}$ inch CROSS-SECTION)

by

D.A.HANCOCK, A.M.I.Mech.E., A.F.R.Ae.S.

JUNE, 1958

MINISTRY OF SUPPLY

SUBJECTS

1. Continuous rod warheads.
2. Lethality.
3. Aerial targets.
4. Kill probability.
5. Warheads - Test results.

10. (Secret report)

ADDED ENTRIES

I Hancock, D. A.

II

III

IV

V Project No.

VI Contract No.

CONFIDENTIAL

U.D.C. No. 623.565.22:623.562.5

3

Technical Note No. Mech. Eng. 261

6 June 1958

2

ROYAL AIRCRAFT ESTABLISHMENT 2B

(FARNBOROUGH)

4

CONTINUOUS-ROD WARHEAD LETHALITY TRIALS AGAINST STATIC AIRCRAFT TARGETS (RODS $\frac{1}{4}$ INCH × $\frac{1}{4}$ INCH CROSS-SECTION)

by

5

D.A. Hancock, A.M.I.Mech.E., A.F.R.Ae.S.

R.A.E. Ref: ME/B3/9072/DAH

SUMMARY

This Note records the results of six static detonations of an experimental type of continuous-rod warhead, with $\frac{1}{4}$ inch square-section rod element, against stationary airframe and turbo-jet engine targets at ground level. An indication of the terminal kill probabilities against various aircraft structures and engines is given.

The warhead is shown to be capable of inflicting lethal damage on most forms of airframe structure, under generally favourable conditions of attack at distances up to about 40 ft from the burst position, and also of causing sufficient damage to put individual jet-engines out of action.

In general, it appears that the $\frac{1}{4}$ inch square-section continuous-rod warhead - as tested - is capable of achieving a reasonable standard of terminal lethality against airframe structures and power plants.

CONFIDENTIAL

CONFIDENTIAL

LIST OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

CONFIDENTIAL

1 INTRODUCTION

1.1 During development trials of various "second-generation" warheads for anti-aircraft guided missiles, firings were made with experimental continuous-rod warheads against a number of static aircraft targets. These warheads had been developed as research items, and the firings, which were part of the normal development trials conducted by A.R.D.E., were used to provide data on:-

(a) The vulnerability of aircraft structures and gas-turbine engines to this form of attack, and

(b) The terminal lethality of this type of warhead.

1.2 The trials reported in this Note were of six similar warheads incorporating $\frac{1}{4}$ inch × $\frac{1}{4}$ inch cross-section rods. The firings were made by the P.E.E., Shoeburyness, during 1957.

Results of similar trials with warheads having $3/16$ inch × $3/16$ inch cross-section rods have been recorded in an earlier Note[1].

2 DESCRIPTION OF WARHEAD

2.1 A continuous-rod warhead consists of a charge of H.E. surrounded by a large number of short rods of steel. Each rod is joined, by welding at the ends to adjacent rods to form a continuous length. Under the forces of the H.E. detonation, the rod structure expands outwards forming a "zig-zag" ring of ever increasing diameter, until a maximum size is reached and the ring breaks up. The maximum size of the continuous ring is defined as the "Maximum Hoop Radius", and is given by:

$$\text{M.H.R.} = (n\ell - \text{total length of welds})/2\pi$$

where: n = the total number of rods
ℓ = the length of a single rod (all rods of equal length).

In practice however, the rod tends to break up before this theortical radius is reached. At the commencement of the trials it was considered by A.R.D.E. that with this particular warhead, rod hoop continuity should be obtainable up to about 66% the M.H.R.

2.2 The warheads used in these trials were made to A.R.D.E. design No.58/762/GE. A view of one, erected ready for detonation, is shown in Fig.1.

2.3 The overall length and diameter of this warhead were 14.8 inches and 10.5 inches respectively, and it had a total filling weight of 26 lb RDX/TNT, 60/40. The steel rod itself was of $\frac{1}{4}$ inch × $\frac{1}{4}$ inch cross-section, and a total of 240 rods were joined together. Central initiation was adopted, using a No.33 electric detonator. The M.H.R. of this warhead was stated to be 37.3 feet, so that a maximum continuous hoop of at least 25 feet radius was anticipated.

3 TARGETS

3.1 The number of suitable targets available for the trials was limited, but because of the localised nature of the damage, it was possible to use some specimens in more than one layout. For the same reason, targets that had received local damage in trials with other weapons were also used satisfactorily. A total of 39 targets, including 12 jet-engines, were used in these trials.

3.2 Where possible, targets similar to those used for previous trials with 3/16 inch × 3/16 inch rods, were employed in order to obtain a comparison of the damaging effects of the two sizes of rod. The results of this comparison have been recorded in a previous paper[2].

3.3 Valiant, Victor, Javelin, Fairey Delta, Comet and V.1000 aircraft structural components were attacked in order to determine the resistance to damage by structures of fairly modern design. Lancaster aircraft rear centre portions of fuselage, Lancaster wings, and R4B replica wing targets, which incorporate concentrated load carrying members in the form of heavy longerons or spar booms, were used to determine the resistance of these items to rod attack. Lancaster wing segments containing fuel tanks, and modified fuselage sections with replica tanks containing water in lieu of fuel were also attacked, to investigate the effects of hydraulic shock waves initiated by rod impact. Some targets were inclined at fairly acute angles to the line of flight of the rods, to determine the tendency of the rods to ricochet at fine angles of attack. Spitfire wings were included, since they have a relatively tough leading-edge to investigate the effects of rods approaching from the head-on direction.

3.4 Derwent, Goblin and Avon jet-engines (unserviceable and non-running) were included in the layouts in order to obtain an indication of their vulnerability to rod attack. The targets used in the six individual layouts are recorded in Figs.2 to 7 inclusive.

4 TRIALS PROGRAMME

4.1 For each of the six firings, a number of targets consisting of various aircraft sections and engines, was mounted in different altitudes in a circular layout around the warhead. Illustrations of two typical target arenas before firing are given in Figs.8a and 8b. In most cases the targets were supported by means of guy-wires or scaffolding. Whilst in each individual firing a constant distance was maintained between the warhead and the impact position on each of the targets, the diameter of the layout was, in successive firings, varied between 40 ft and 132 ft, representing burst distances between 20 ft and 66 ft from the target (see Figs.2 to 7). These diameters were chosen because information of rod continuity and rod damaging potential at various distances above and below the M.H.R. was required.

4.2 The warhead was detonated electrically by the firing circuit of an Argon Lamp Chronograph, which was used to record the velocities of the rods.

4.3 The damage to each target was recorded and where applicable a kill assessment given in terms of category 'A', i.e. the aircraft will fall out of control within five minutes of being hit. The assessments of airframe damage were based on structural considerations only, no allowance being made for fire risks or component damage. Engine assessments were based on the probability that the particular engine affected would cease to function within five minutes of being damaged.

5 RESULTS

5.1 A summary of the results is given in Table 1. Details of the damage caused to the targets, and assessments of kill probability, are given in Table 2. Typical examples of damage are shown in Figs.9 to 17.

5.2 Hoop continuities were assessed by A.R.D.E. representatives.

5.3 The rod velocities which were recorded, were within the range 3,050 ft/sec to 3,630 ft/sec, with a mean value of 3,390 ft/sec, and a standard deviation of 156 ft/sec. It is emphasised that these velocity figures are average

values, measured over the distance from warhead to target. Impact velocities were computed to be within the range 2,700 ft/sec to 3,440 ft/sec with a mean value of 3,130 ft/sec.

6 DISCUSSION OF RESULTS

6.1 The results of the trials, as summarised in Table 1, indicate that the type of $\frac{1}{4}$ inch square-section continuous-rod warhead under consideration can, under some conditions of attack, be effective against airframe structures at distances up to about 40 ft from the burst point. Beyond the 40 ft radius, the effectiveness of the rod appears to be very much reduced. In general, rods which were effective at 20 ft radius were equally effective at 40 ft. The type of aircraft structure, whether incorporating concentrated or distributed load-carrying members, appeared to have little influence on the lethality of the $\frac{1}{4}$ inch square-section rod, though it should be noted that in the case of some structures with distributed load-carrying members, the targets tended to be over-killed. This contrasts with the results of previous trials in which the $^3/16$ inch square-section rod warheads - though effective against modern structures with distributed members - were largely ineffective against the older types having concentrated load-carrying members.

6.2 The influence of the direction of attack on the lethality of the $\frac{1}{4}$ inch rod is shown both in the Spitfire wing firings, where at a common distance the lethality varied from zero to 100A for two different attack conditions, and in the fine angle attacks against "R4B" replica wing targets, where ricochet occurred at 33 ft radius, causing no significant damage.

6.3 Trials against the targets with replica fuel tanks, containing water, showed that the pressure-wave set-up by the passage of the rod tends to increase the extent and severity of the damage inflicted.

6.4 It must be emphasized that, in most of the trials against airframe structures, "simple" conditions of attack were imposed, i.e. attacks at normal to the surface concerned. Thus, in practice, results might be expected to be somewhat less favourable to the warhead than indicated from the trials.

6.5 The $\frac{1}{4}$ inch rod warhead proved fully effective against Derwent engines at 20 ft and 25 ft radius, Goblin engines of 25 ft and 40 ft radius, and Avon engines at 33 ft and 66 ft radius. It is likely that most fair hits, at up to 66 ft radius, on a running turbine engine by even a moderate length of rod would cause damage sufficient to stop that engine.

7 CONCLUSIONS

7.1 The type of warhead considered, with $\frac{1}{4}$ inch square-section continuous-rod element, appears capable of inflicting lethal damage on most forms of airframe structure under favourable conditions of attack. This applies to targets up to about 40 ft from the burst point, though the theoretical maximum continuous-hoop radius of the warhead is only about 37 ft. It is largely independent of the type of airframe structure involved - whether the primary structural members are concentrated or distributed. The severity of the damage tends to be greater when the rod enters an airframe which is largely occupied by liquid filled tanks.

7.2 Strikes on turbine engines are effective at distances up to 40 ft from the burst point, and it is likely that a fair hit by even a moderate length of "broken" rod, at almost any position on a running engine, at a distance up to 66 ft, would cause damage sufficient to stop the engine.

7.3 In general, it appears that the $\frac{1}{4}$ inch square-section continuous-rod warhead - as tested - is capable of achieving a reasonable standard of terminal lethality against airframe structures and power plants. Its performance under some more difficult conditions of attack has yet to be established.

8 FURTHER WORK

8.1 Further investigations, with various cross-sectional sizes of rod, are proposed against more complex targets and under more difficult conditions of attack. Also, an endeavour will be made, in conjunction with A.R.D.E. to determine Rod Damage Laws.

LIST OF REFERENCES

Ref.No.	Author	Title, etc.
1	Hancock, D.A.	Continuous-rod warhead lethality trials against static aircraft targets (rods 3/16 inch × 3/16 inch cross-section). R.A.E. Technical Note No. Mech. Eng.249. December 1957. SECRET.
2	Hancock, D.A.	A comparison of the terminal lethality of 3/16 inch and $\frac{1}{4}$ inch square section continuous-rod A.A. warheads. R.A.E. Deptl. Memo. No. Mech. Eng.174. November 1957. SECRET.

ATTACHED:

Tables 1 and 2
Fig.1 - Neg No. 136,869
Figs.2 to 7 SME.82195/R to SME.82200/R
Figs.8 to 16 Neg. No. 136,870 to 136,879
Detachable abstract cards

ADVANCE DISTRIBUTION:

DG/GW		DARDE	
D/GWRD	(Action)	TIL	60
DGWTD		Director RAE	
DA (Mech)		DDRAE (A)	
DG of A		DDRAE (E)	
DDGFS		GW Dept RAE	
DDGG		Arm Dept RAE	
DDG(RAF)		RAE Library	
DA Arm		RAE Bedford Library	
Sec OB	2	Pats 1/RAE	
GW/P&W			

Technical Note No. Mech. Eng.261

TABLE 1

Summary of results of trials

Distance of Target, from position of detonation:-	Lethality of Warhead (Category "A" Damage)				
	20 ft	25 ft	33 ft	40 ft	66 ft
STRUCTURAL TARGETS					
(a) With distributed load - carrying members					
Valiant fuselage:	100A				
Valiant wing:		100A		100A	
Vickers 1000 fuselage:					0 : 0
Victor wing:		100A	100A	100A	
Fairey Delta airframe:		100A		100A	
Comet wing:					0
Javelin wing:					0
(b) With concentrated load - carrying members					
Spitfire wing. Attack from below:	100A				
Spitfire wing. Attack from ahead:	0				
Lancaster fuselage (Empty):	100A	100A		100A	0
Lancaster fuselage (with tanks containing water):			100A		100A
Lancaster wing (Empty):		50A			0
Lancaster wing (with tanks containing water:		100A			
"R4B" Replica wing (at normal):		100A 100A			
"R4B" Replica wing (at 10^{o} angle):			0. 0. (Ricochet)		
ENGINE TARGETS					
Derwent (Centrifugal flow compressor):	100A 100A	100A 100A			
Goblin (" " "):		100A 100A		100A 100A	
Avon (Axial flow compressor):			100A 100A		100A 100A

TABLE 2

Details of damage to aircraft targets

Target	Damage	A/C Kill Assessment
1 Valiant A/C Fuselage		
Target 3. Layout 1. Radius 20 ft Impact at normal across fuselage.	50% circumference of skinning cut. More than 50% of stringers severed. Bomb bay wall cut.	100% A
2 Valiant A/C Wing		
(a) Target 4. Layout 3. Radius 25 ft. Impact at normal across wing upper surface	100% chordwise cut in upper surface skinning. All upper surface stringers severed. Front spar top boom and rear spar top boom severed. 16 lower surface stringers severed. Front spar lower boom flange cut. (see Fig.9)	100% A
(b) Target 4. Layout 4. Radius 40 ft. Impact at normal across wing upper surface.	55% chordwise cut in upper surface skinning. 44% of stringers severed. Front spar top boom and rear spar top boom severed. 77% of rear spar web cut.	100% A
3 V.1000 A/C Fuselage		
(a) Target 2. Layout 6. Radius 66 ft. Impact at 49° to normal across fuselage.	Cuts totalling 114 in. (approx. 20% circumference) in skinning 17 stringers severed. 5 frames severed.	0
(b) Target 1. Layout 6. Radius 66 ft. Impact at normal across fuselage.	Cuts totalling 80 in. (approx. 4% circumference) in skinning. 17 stringers severed. 3 frames severed. 5 floor beams severed.	0

TABLE 2 (cont'd)

Target	Damage	A/C Kill Assessment
4 Fairey Delta I A/C		
(a) Target 1. Layout 3. Radius 25 ft. Impact at 45° to normal along wing span. Port tank $\frac{7}{8}$ filled with water.	Rod cut continuous in fuselage upper surface and stringers. Rod cut continuous across starboard wing upper surface. 10 in. removed from front spar upper boom flange with a further 12 in. crack. 4 ribs severed and one 10% damaged. 2 ft. wide row of fragment holes across lower surface skinning. Rod cut continuous across port wing upper surface, with a hole 30 in. × 20 in. at the root end and skin bulged 6 in. outwards. Two chordwise cracks 10 in. and 16 in. in skinning. Front spar, top boom and web 80% severed. 2 ft wide row of fragment holes across lower surface skinning. (See Fig.10)	100% A
(b) Target 1. Layout 4. Radius 40 ft. Impact at 45° to normal along wing span. Port tank $\frac{7}{8}$ filled with water	16 in., 10 in. and 48 in. cuts in fuselage upper surface skinning with 6 stringers severed. Port wing fuel tank panel detached. Front spar boom 80% severed. 2 ribs severed. Fragment holes in lower surface. 46 in. spanwise cut in starboard wing upper surface. Front spar boom severed. 3 ribs severed. Fragment holes in lower surface.	100% A
5 Spitfire A/C Wing		
(a) Target 1. Layout 1. Radius 20 ft. Impact normal to wing from 45° below dead ahead.	Wing completely severed 6.5 ft from the root end. (See Fig.11(a))	100% A
(b) Target 2. Layout 1. Radius 20 ft. Impact at normal to wing leading edge.	18 in. cut in leading-edge skinning. (See Fig.11(b))	0
6 Lancaster A/C Fuselage		
(a) Target 4. Layout 1. Radius 20 ft. Impact at normal across fuselage	50% circumference of skinning cut. 27 stringers severed. One longeron cut and cracked. Other longeron 50% damaged.	100% A

TABLE 2 (cont'd)

Target	Damage	A/C Kill Assessment
6 Lancaster A/C Fuselage (cont'd)		
(b) Target 2. Layout 3. Radius 25 ft. Impact at normal along fuselage.	Cut continuous for length of target (20 ft) in skinning. All frames severed (15 off) on entry face 6 frames also severed on exit face 3 stringers cut. (See Fig.12)	100% A
(c) Target 2. Layout 4. Radius 40 ft. Impact at normal along fuselage	Cuts totalling 24 ft in skinning along length of target. All frames severed (15 off) on entry face. 5 frames also severed on exit face. 3 stringers cut.	100% A
(d) Target 2. Layout 5. Radius 33 ft. Fuselage fitted with simulated fuel tanks, $\frac{7}{8}$ filled with water. Impact at normal along fuselage.	Fuselage side cut for full length of target and opened outwards from floor to roof.	100% A
(e) Target 5. Layout 6. Radius 66 ft. Impact at 80° to normal across fuselage.	2 holes, 13 in. × 4 in. and 11 in. × 14 in. in skinning. Ricochet graze on longeron. 1 stringer bent.	0
(f) Target 6. Layout 6. Radius 66 ft Fuselage fitted with simulated fuel tanks $\frac{7}{8}$ filled with water.	Skinning holed 18 in. × 79 in., with longitudinal seam opened, total length of damage 12 ft. 5 frames completely severed, 5 frames partially severed. 3 stringers completely severed, 5 stringers partially severed.	100% A
7 Lancaster A/C Wing		
(a) Target 3. Layout 2. Radius 25 ft. Impact at normal across upper surface.	100% chordwise cut in upper surface and stringers. Flange of rear spar upper boom severed. $\frac{1}{2}$ in. deep groove in front spar upper boom. Miscellaneous holes up to 15 in. × 12 in. in lower surface, including 8 stringers severed. (See Fig.13)	50% A
(b) Target 7. Layout 6. Radius 66 ft. Impact at 75° to normal across upper surface.	2 cuts, 13 in. and 14 in. in leading-edge skinning. 2 ft graze plus 6.5 ft cut and 7.5 ft cut in interspar skinning. Front spar upper boom nicked and the top of 2 ribs cut.	0

TABLE 2 (cont'd)

Target	Damage	A/C Kill Assess-ment
7 Lancaster A/C Wing (cont'd)		
(c) Target 4. Layout 2. Radius 25 ft. Fuel tanks $\frac{7}{8}$ filled with water. Impact at normal across upper surface.	Upper surface torn and bulged 32 in. outwards for 55 in. span. Rear spar upper boom 50% severed. Front spar upper boom grooved $\frac{1}{4}$ in. deep. Leading-edge severed. Lower surface bulged for 6 ft span with rivets of spanwise centre-joint sheaved. Cut $2\frac{1}{2}$ in. × 1 in. from flange of rear spar lower boom. (See Fig.15)	100% A
8 R4B Replica Target		
(a) Target 1. Layout 2. Radius 25 ft. Impact at normal across upper surface	100% chordwise cut in upper surface skinning 8 stringers severed, and one 75% severed. One I-beam stringer 40% severed and other 30% severed (upper surface). Front spar upper boom flange cut and rivets sheared in leg for 10 in. span. Rear spar upper boom flange cut. Miscellaneous holes in lower surface skinning. 3 stringers severed, and four 50% severed. Both I-beam stringers (lower surface) 75% severed. (See Fig.15(a))	100% A
(b) Target 2. Layout 2. Radius 25 ft. Impact at normal across lower surface	100% chordwise cut in lower surface skinning with all stringers and I-beams severed. Front spar lower boom grooved $\frac{1}{2}$ in.deep. Rear spar lower boom grooved $\frac{3}{8}$ in. deep. 2 stringers severed, three 50% severed and one 80% severed on upper surface which was holed by fragments. Front spar upper boom leg severed and split for 42 in. span. (See Fig.15(b))	100% A
(c) Target 3. Layout 5. Radius 33 ft. Impact at 80° to normal across upper surface.	Rods ricocheted. Tears in skinning 7, 8, 12, 13, 15, 15 and 16 in. long. Holes $1\frac{1}{2}$ in. × 3 in., $1\frac{1}{2}$ in. × 6 in. 2 in. × 4 in.	0
(d) Target 4. Layout 5. Radius 33 ft. Impact at 80° to normal across lower surface.	Rods ricocheted. Interspar skinning scored by rods, almost continuous between spars, one hole 2 in. × 6 in., and some removal of rivet heads. T.E. disrupted.	0

TABLE 2 (cont'd)

Target	Damage	A/C Kill Assessment
9 Victor A/C Wing		
(a) Target 3. Layout 3 Radius 25 ft. Impact at normal across upper surface.	Cut continuous across upper surface (10 ft). All stringers and spar upper booms (4 off) severed. Sandwich skinning on lower surface between spars severed (33, 36 and 33 in.) Four shatter cracks up to 2 ft long. (See Fig.16)	100% A
(b) Target 3. Layout 4. Radius 40 ft. Impact at normal across upper surface.	Upper surface:- First spar boom severed, plus 12 in. cut with 12 stringers severed. Second spar boom severed, plus 12 in. cut with 4 stringers severed, and a 20 in. cut with 9 stringers severed. Third spar boom severed with 10 in. span of web removed, plus 23 in. cut with 3 stringers severed. Fourth spar boom severed, plus 21 in. cut with 1 stringer severed. Total of 70% chordwise skinning severed. Lower surface:- First spar boom severed, plus 26 in. cut with 9 stringers severed. Two fragment holes 5 in. × 2 in. and 3 in. × 2 in. 17 in. cut with 6 stringers severed. 11 in. cut with 4 stringers severed. 13 in. cut with 5 stringers severed. Total of 50% chordwise skinning severed.	100% A
(c) Target 1. Layout 5. Radius 33 ft Impact at normal across upper surface	Total length of cuts in upper surface = 23.75 ft almost continuous across chord. Outer jet pipe frame cut, rear spar top boom severed. Mid-spar top boom severed, and front spar top boom leg severed. Row of fragment holes of 130 in. aggregate length in lower surface with rear spar lower boom 10% severed.	100% A
10 Comet A/C Outer Wing		
Target 3. Layout 6. Radius 66 ft Impact at normal across upper surface.	64 in. aggregate of 5 cuts in upper surface skinning with 5 stringers severed. Holes, 5 in. × 3 in., 3 in. × 1 in., 5 in. × 4 in., 6 in. × 6 in. and 14 in. × 7 in. in lower surface skinning with 2 stringers severed. Front spar top boom severed.	0

TABLE 2 (cont'd)

Target	Damage	A/C Kill Assessment
11 Javelin A/C Wing		
Target 4. Layout 6. Radius 66 ft. Impact at 60° to normal across upper surface.	18 in. cut with top of 2 ribs severed, and 25 in. cut with top of 2 ribs severed in upper surface skinning.	0
		Engine Kill Assessment
12 Derwent Jet Engine		
(a) Target 5. Layout 1. Radius 20 ft Impact at normal along engine axis.	Nos.3,4,5 and 6 combustion chambers holed, torn or buckled. Wheelcase holed. 4 intake supporting struts damaged. 13 guide vanes damaged. 4 intake guide rings holed. Compressor casing damaged and holed. Nozzle box holed, primary and main burner fuel lines severed.	100% A
(b) Target 6. Layout 1. Radius 20 ft Impact at normal across engine axis.	Nos.5,6,7,8 and 9 combustion chambers holed, torn or buckled. Turbine casing holed and rear bearing damaged.	100% A
(c) Target 5. Layout 2. Radius 25 ft Impact at normal, 45° across engine axis.	H.P. fuel line severed in 4 places. L.P. fuel filter damaged. Nos.1,2,3 and 6 combustion chambers holed or buckled. Oil system including tank badly damaged. Compressor casing holed and damaged. (See Fig.17(a))	100% A
(d) Target 6. Layout 2. Radius 25 ft Impact at normal, 45° across engine axis.	Fuel line to No.10 burner severed. Oil supply pipe to bearings severed. Nos. 5,6,7,8,9 and 10 combustion chambers holed and severed. Compressor casing holed and cracked.	100% A
13 Goblin 2. Jet Engine		
(a) Target 5. Layout 3. Radius 25 ft Impact at normal, 45° across engine axis.	Fuel pipe and burner ring severed. Oil pipes to front bearings severed. Nos. 8,12 and 13 combustion chambers holed and severed, Nos.7,9,10,11 and 14 dented. Compressor and turbine casings holed and damaged.	100% A
(b) Target 6. Layout 3. Radius 25 ft. Impact at normal along engine axis.	H.P. fuel lines severed. Nos.1,2,3,4,8 and 16 combustion chambers holed and distorted. Compressor casing fractured. Turbine casing holed and damaged.	100% A

TABLE 2 (cont'd)

Target	Damage	Engine Kill Assessment
13 Goblin 2. Jet Engine (cont'd)	-	
(c) Target 5. Layout 4. Radius 40 ft. Impact at normal along engine axis.	Nos.8,11,12 and 13 combustion chambers holed and distorted. Nos.10,11,12 and 13 nozzles torn and distorted. Compressor and turbine casings holed and fractured. (See Fig.17(b))	100% A
(d) Target 6. Layout 4. Radius 40 ft. Impact at normal across engine axis.	Oil lines to rear bearing severed Nos.1,9,10,11,12,13,14,15 and 16 combustion chambers holed and distorted.	100% A
14 Avon RA2. Jet Engine		
(a) Target 5. Layout 5. Radius 33ft. Impact at normal along engine axis	5 holes in compressor casing, 5 blades dislodged. Primary and main fuel lines severed. Nos.1,2, and 8 combustion chambers holed and damaged. Turbine shroud ring cut.	100% A
(b) Target 6. Layout 5. Radius 33 ft. Impact at normal 45° across engine axis.	Compressor casing holed and fractured. 10 stator blades dislodged, 4 others damaged. Fuel lines severed. Nos. 4,5 and 6 combustion chambers holed and distorted.	100% A
(c) Target 8. Layout 6. Radius 66 ft. Impact at normal along engine axis.	L.P. and H.P. fuel lines severed. Rear part of flame tube cut. Compressor casing holed and cut. 7 stator blades dislodged and 8 rotor blades damaged.	100% A
(d) Target 9. Layout 6. Radius 66 ft. Impact at normal across engine axis.	L.P. and H.P. fuel lines severed. Compressor casing holed, 9 stator blades dislodged and 2 rotor blades damaged.	100% A

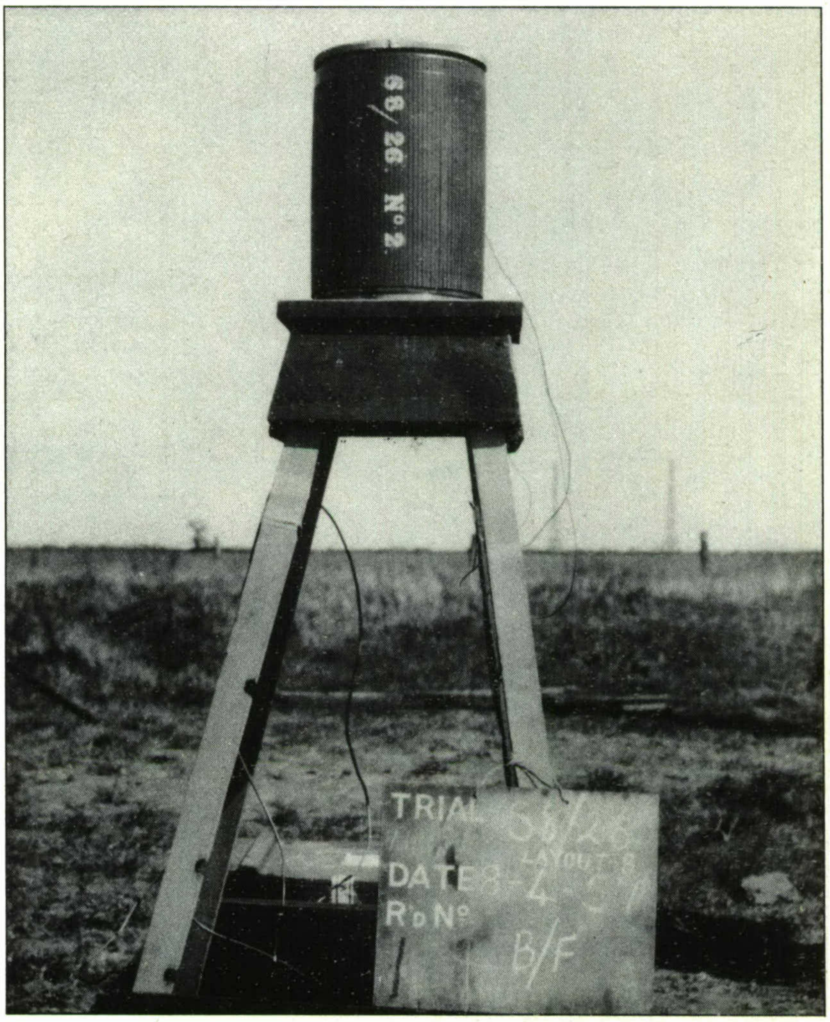


FIG. 1. WARHEAD BEFORE DETONATION

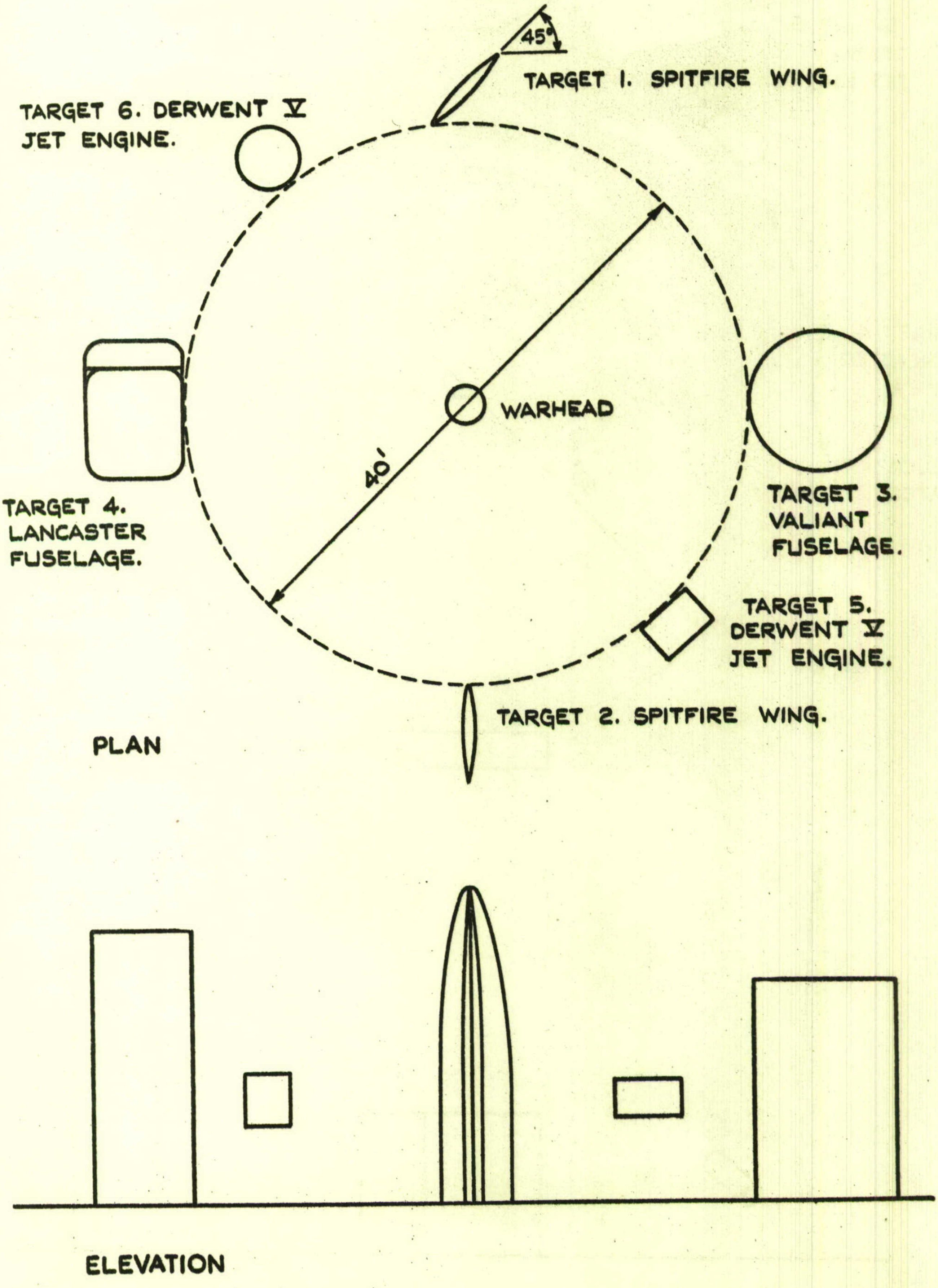


FIG. 2. TARGET LAYOUT No. 1.

FIG. 3.

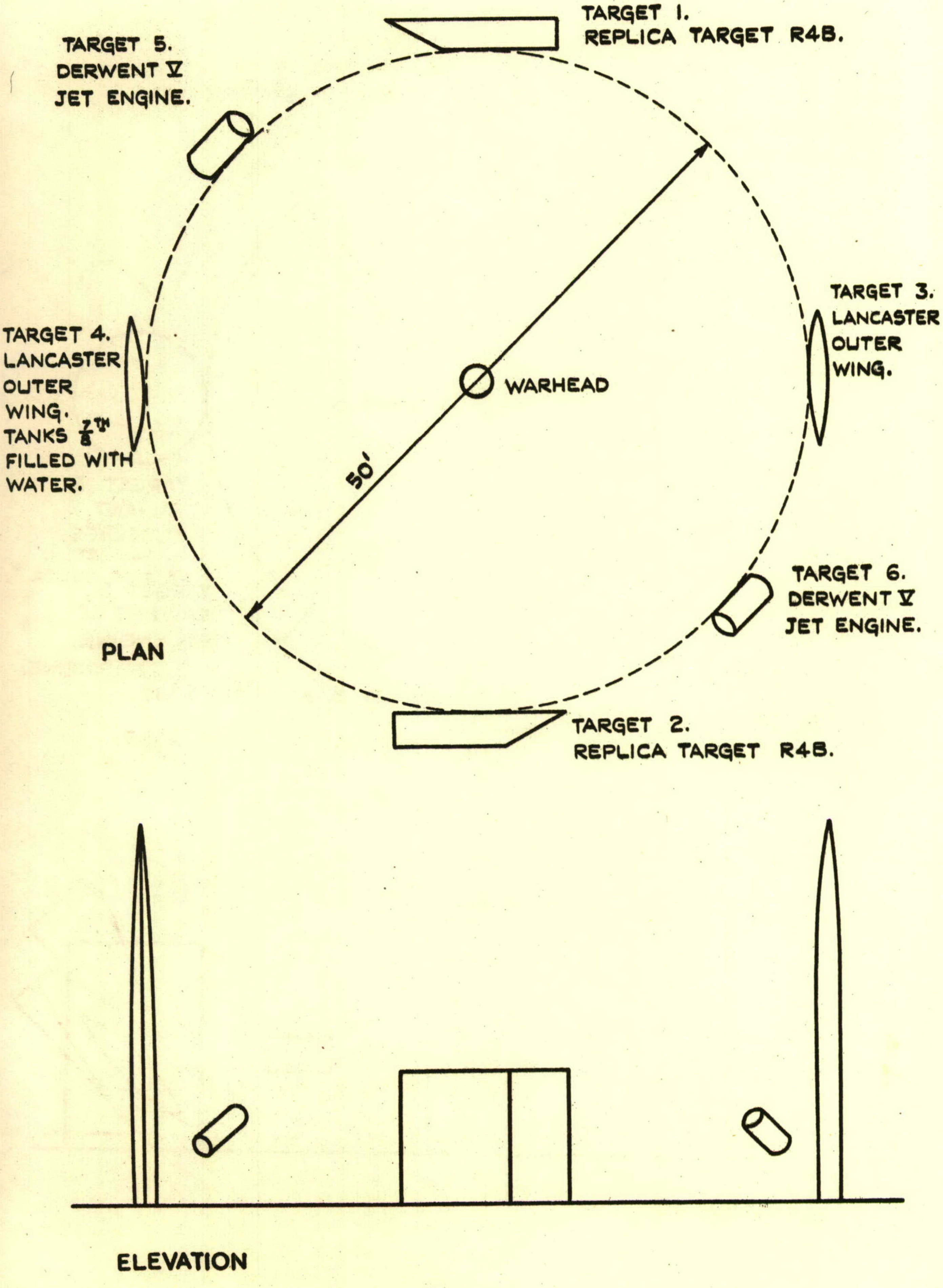


FIG. 3. TARGET LAYOUT No. 2.

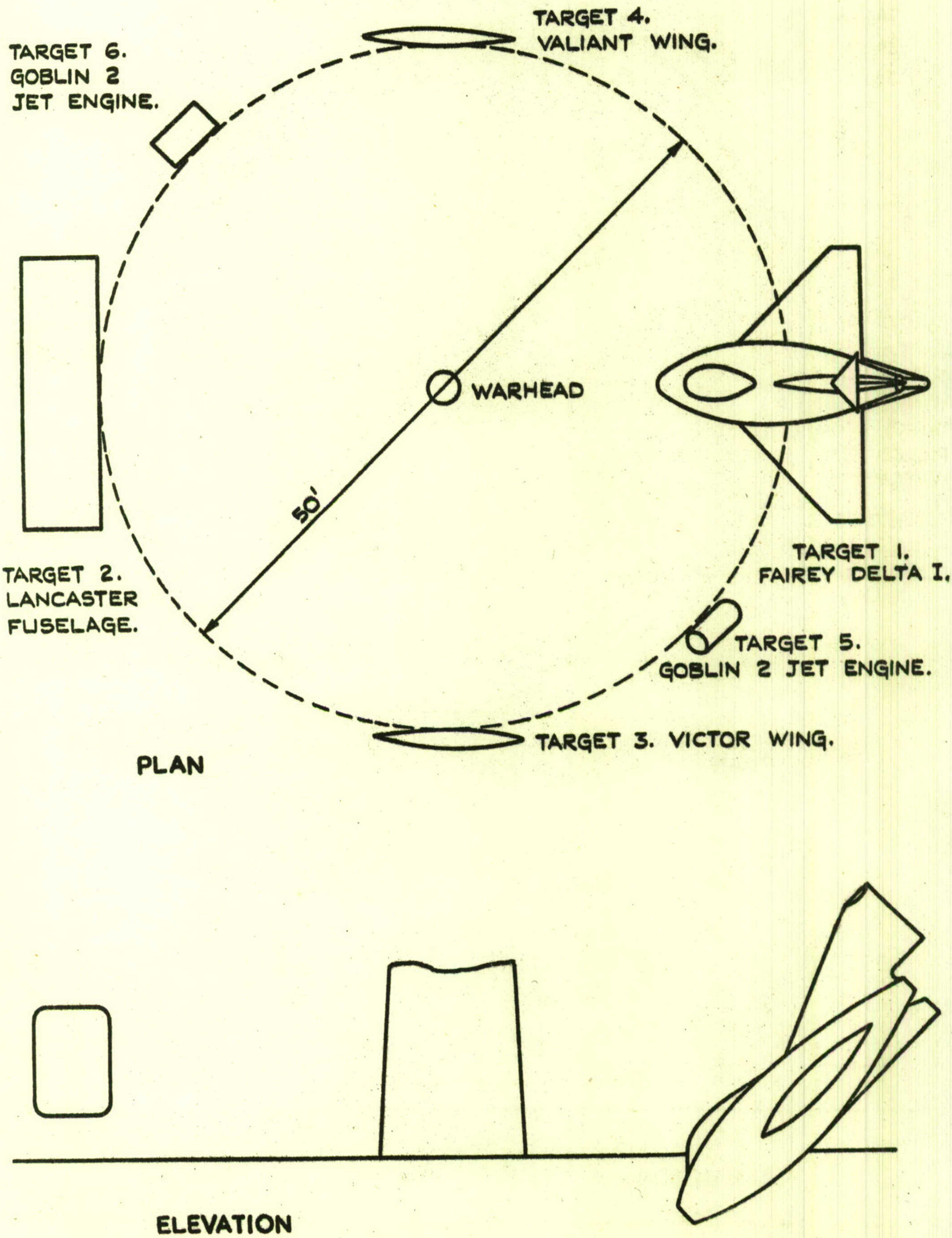


FIG. 4. TARGET LAYOUT No. 3.

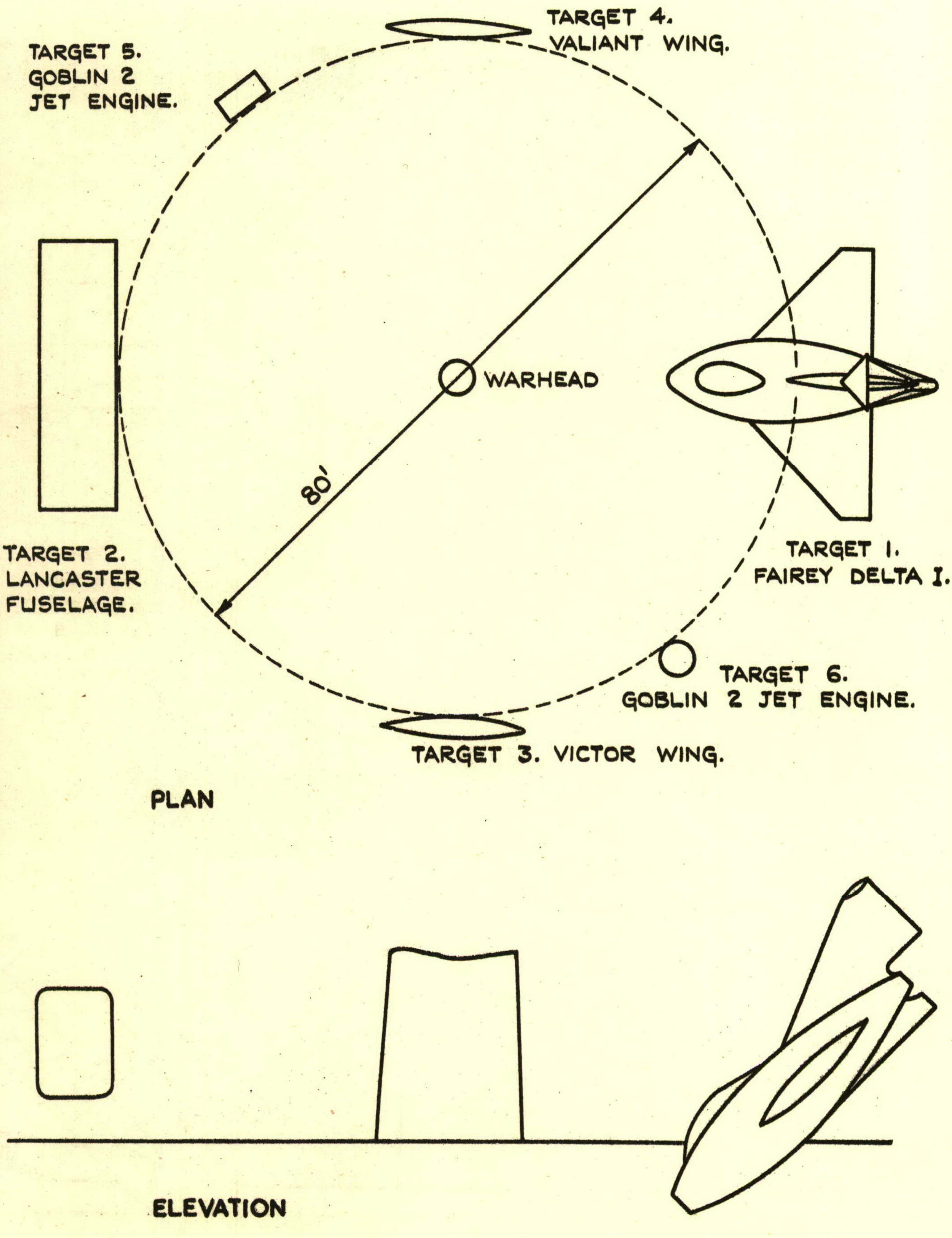
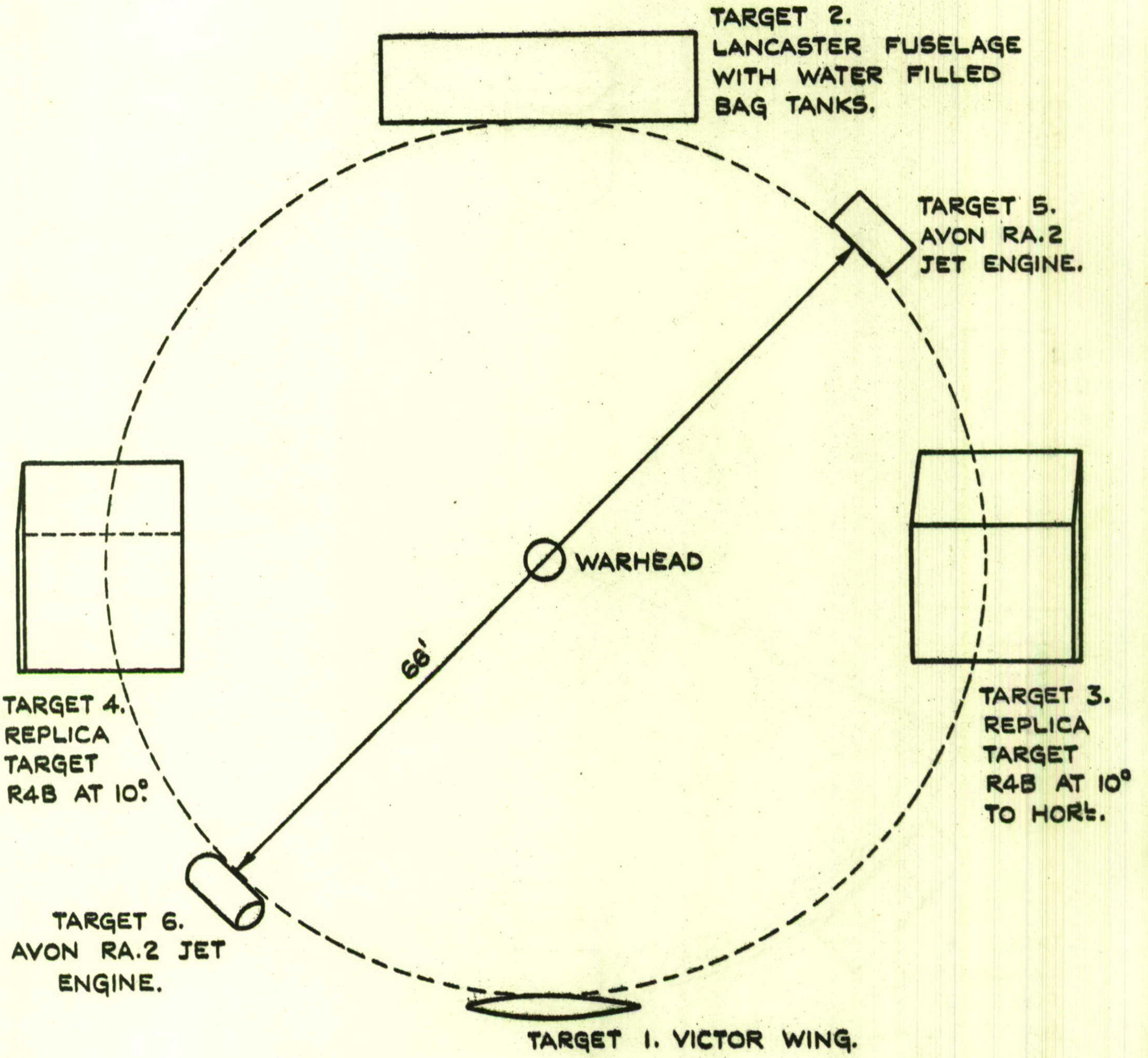
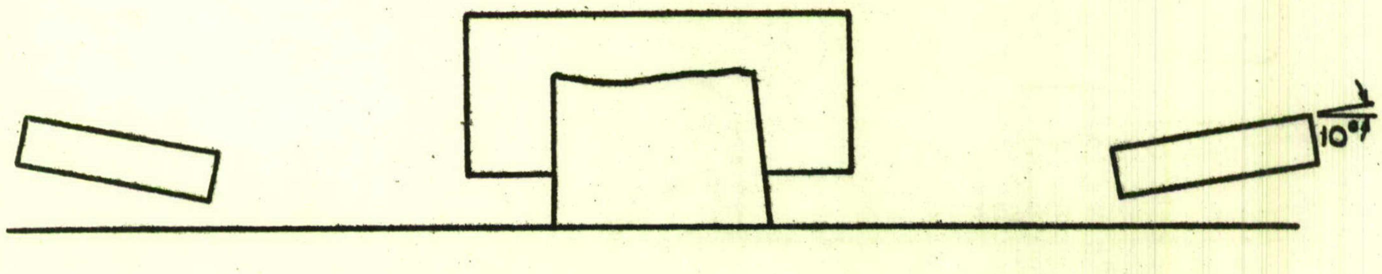


FIG. 5. TARGET LAYOUT No. 4.



PLAN



ELEVATION

FIG. 6. TARGET LAYOUT No. 5.

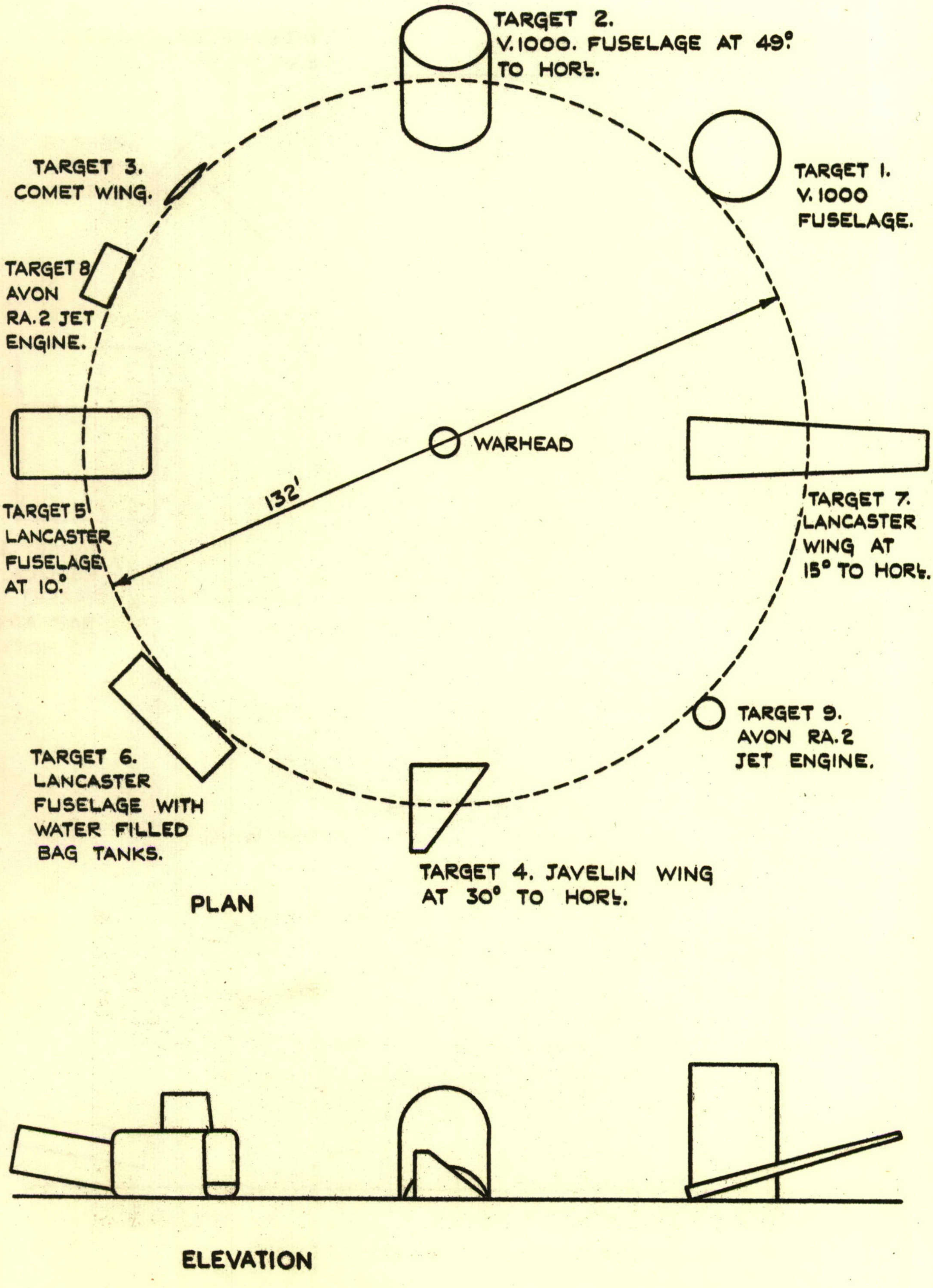


FIG. 7. TARGET LAYOUT No. 6.

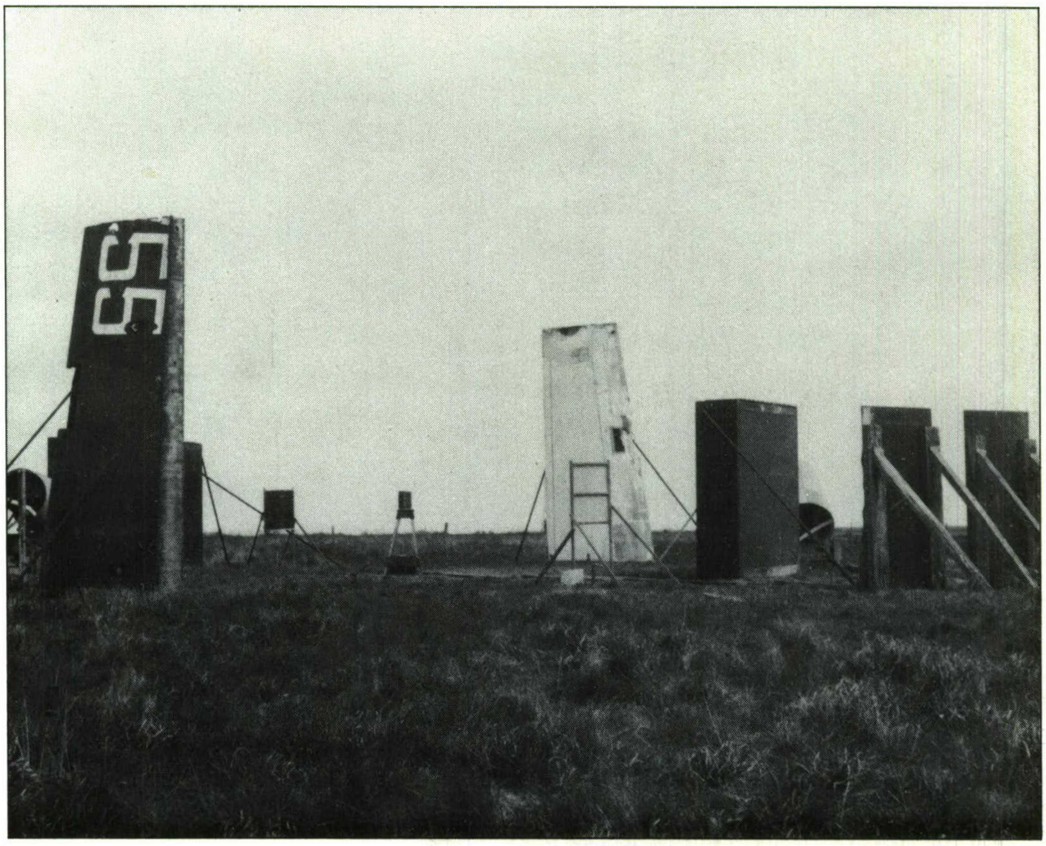


FIG.8a. LAYOUT No.2 BEFORE FIRING

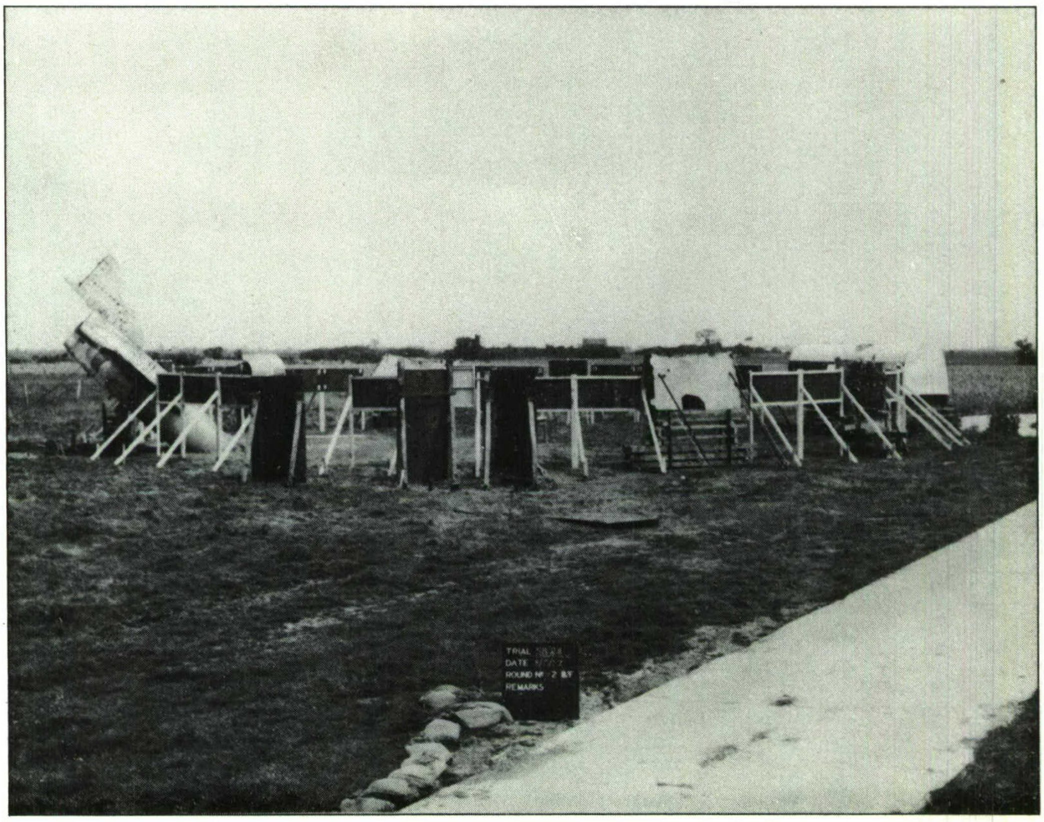


FIG.8b. LAYOUT No.4 BEFORE FIRING

FIG.8a & 8b. TARGET ARENAS

FIG.9a. ROD ENTRY

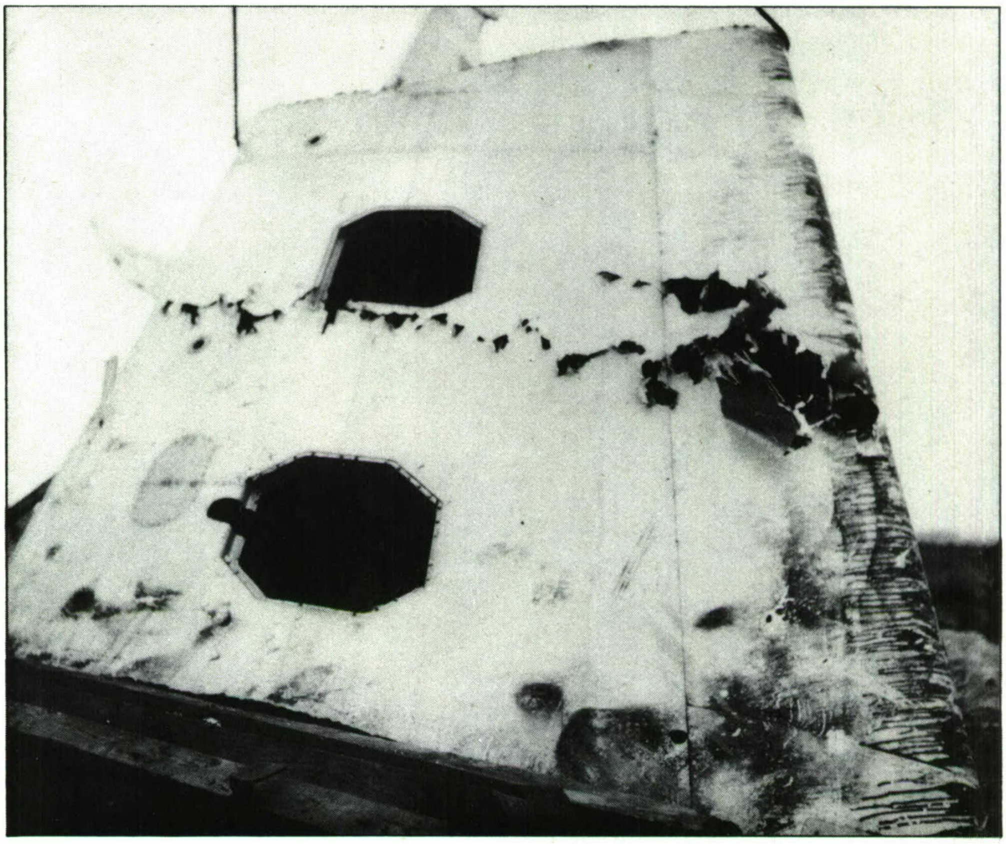


FIG.9b. ROD EXIT

FIG.9a & 9b. VALIANT WING (*Table 2; 2a*)

R.A.E. 136871 58

FIG.10

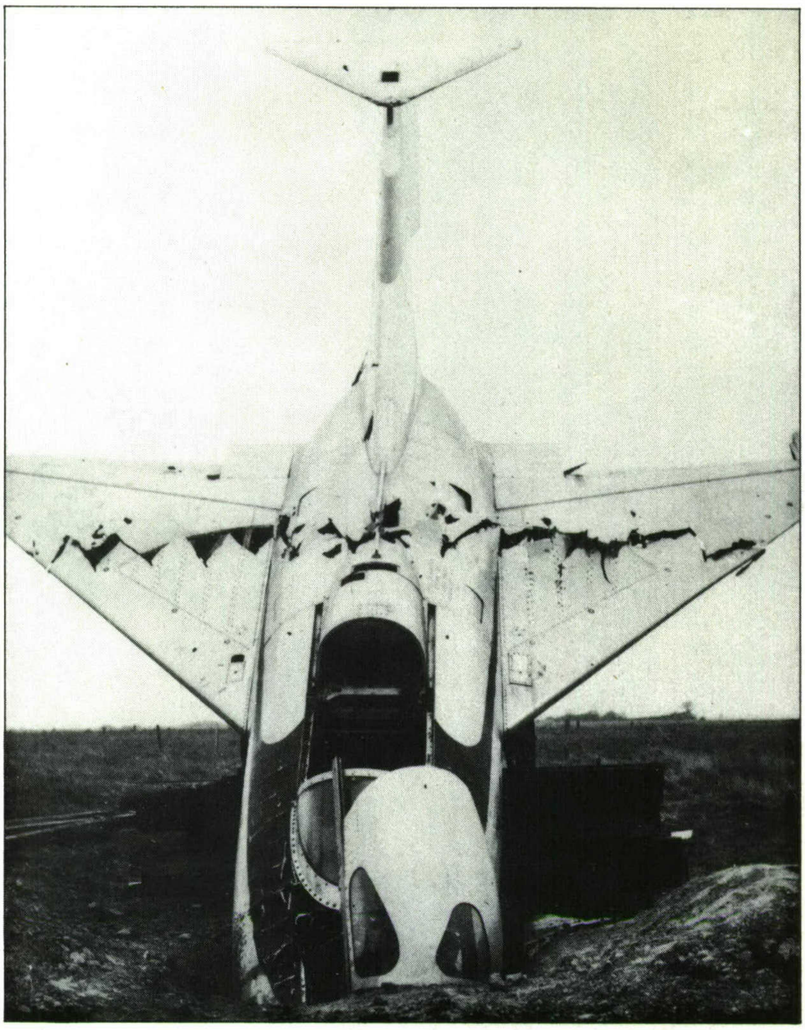


FIG.10a. ROD ENTRY

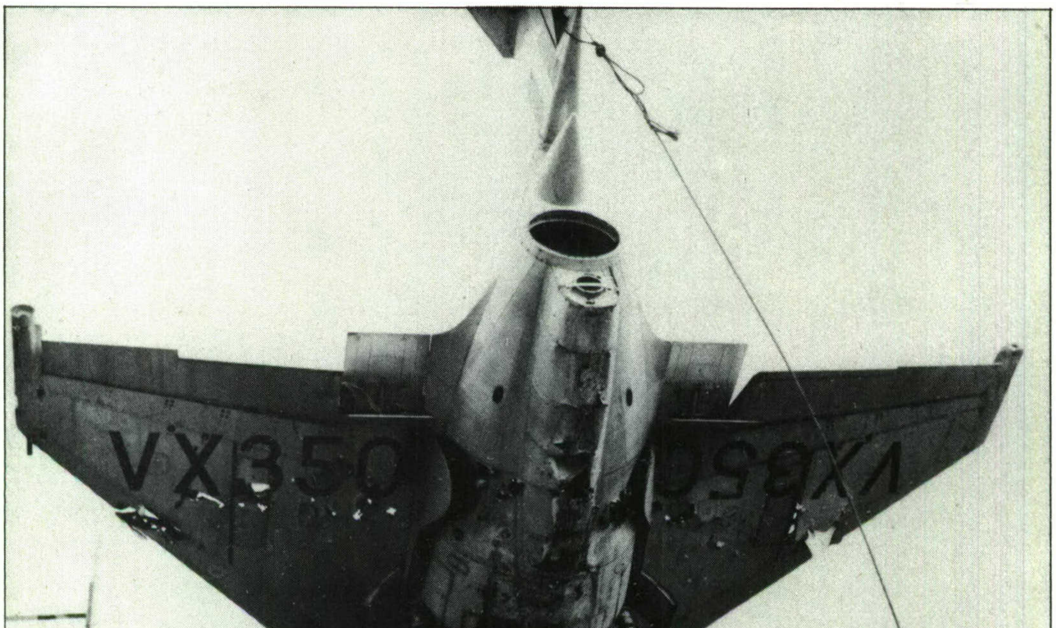


FIG.10b. ROD EXIT

FIG.10a & 10b. FAIRY DELTA I AIRCRAFT (*Table 2; 4a*)

FIG.11

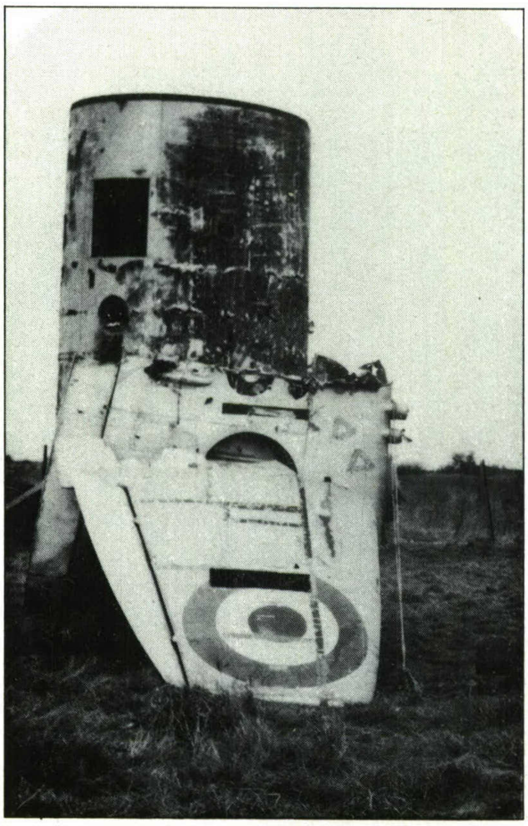


FIG.11a. AFTER FIRING

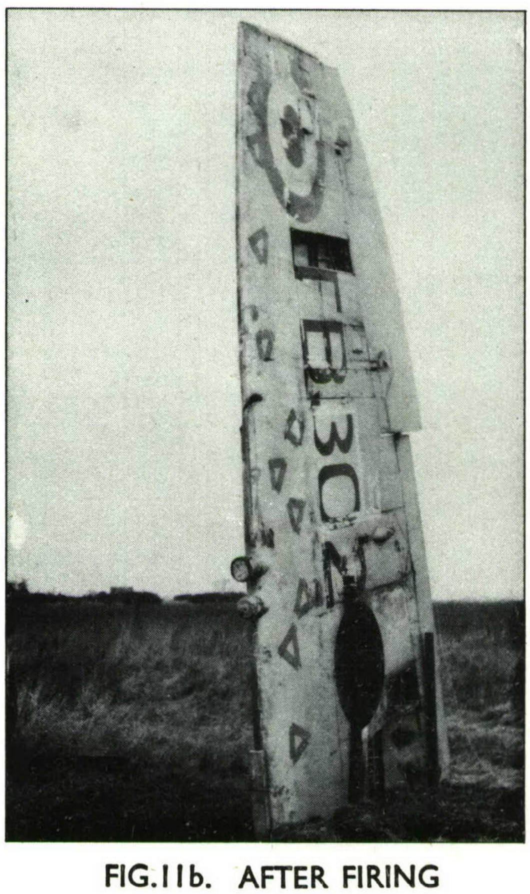


FIG.11b. AFTER FIRING

FIG.11a & 11b. SPITFIRE WINGS (*Table 2; 5a & 5b*)

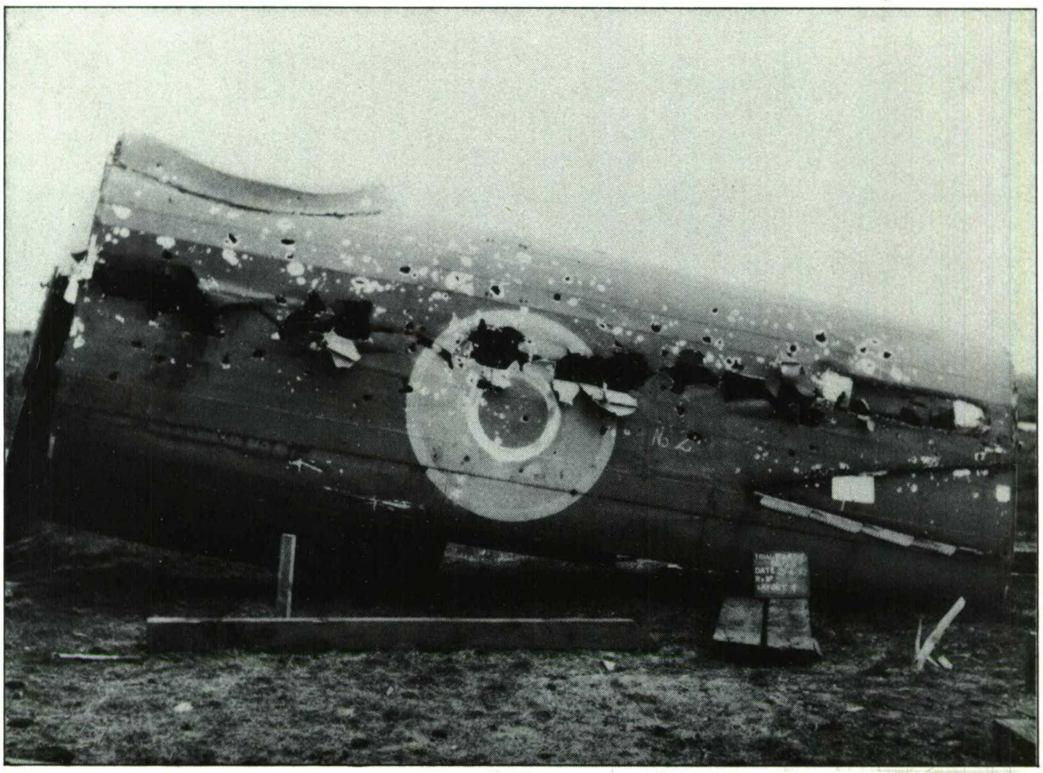


FIG. 12a. ROD ENTRY

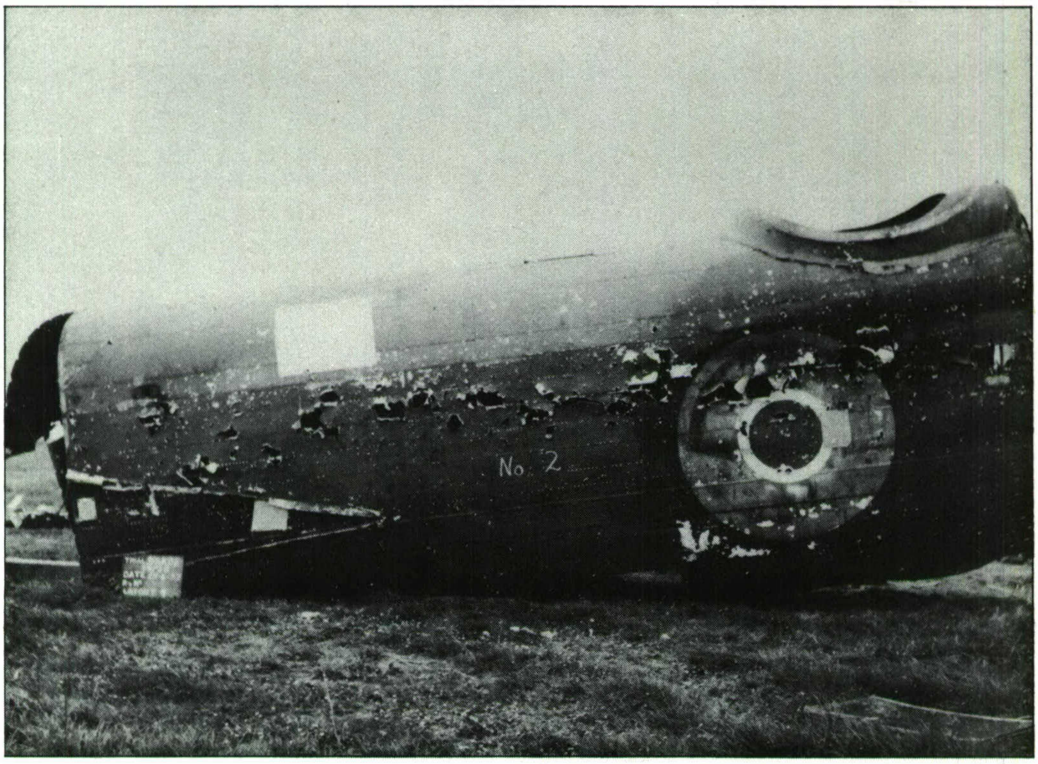


FIG. 12b. ROD EXIT

FIG. 12a & b. LANCASTER AIRCRAFT OUTER WING, TANKS EMPTY.
(*Table 2; 7a*)

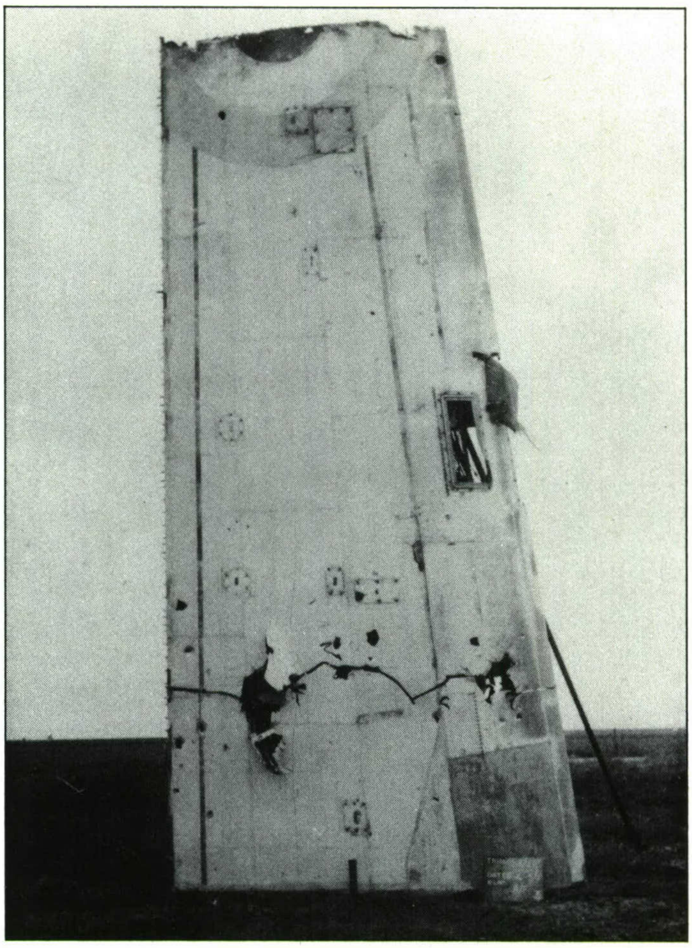


FIG.13a. ROD ENTRY

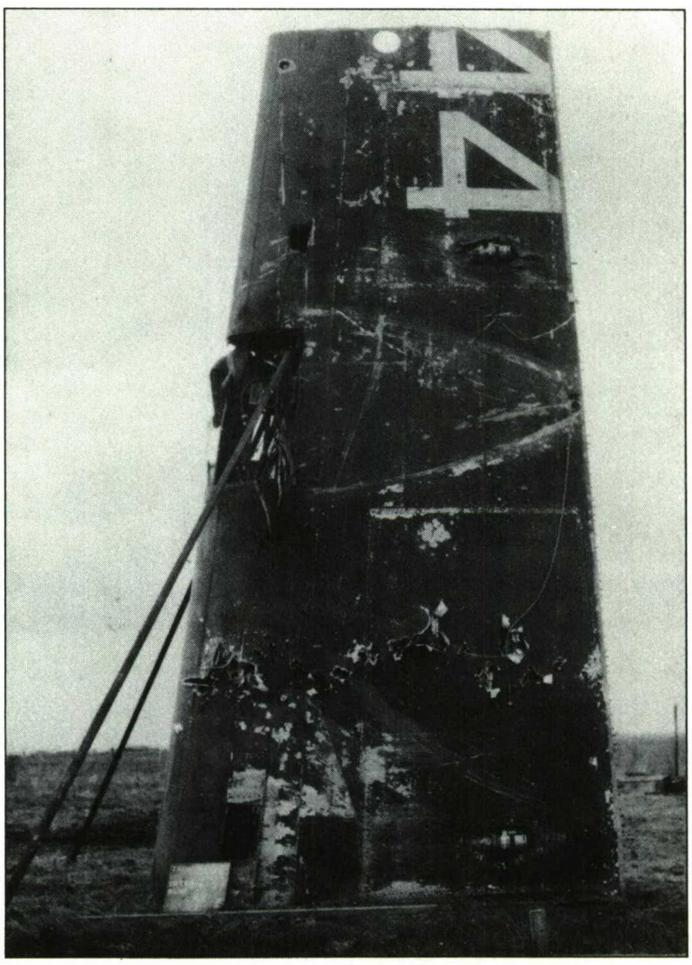


FIG.13b. ROD EXIT

FIG.13a & 13b. LANCASTER AIRCRAFT OUTER WING, TANKS EMPTY. (*Table 2; 7a*)

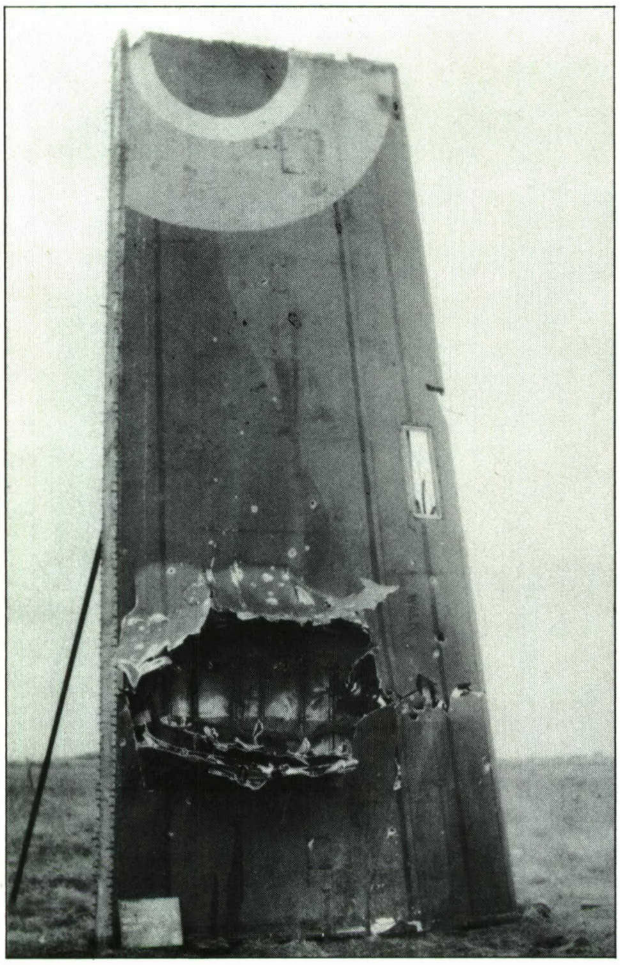


FIG. 14a. ROD ENTRY

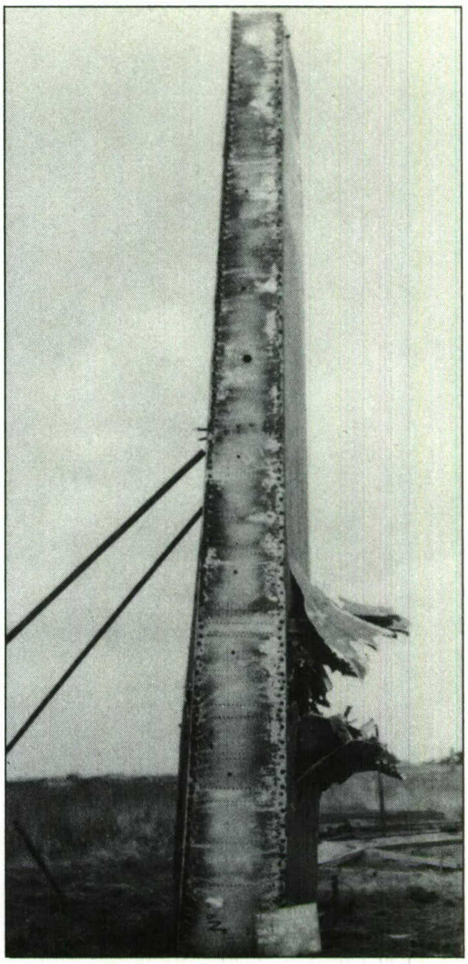


FIG. 14b. ROD ENTRY

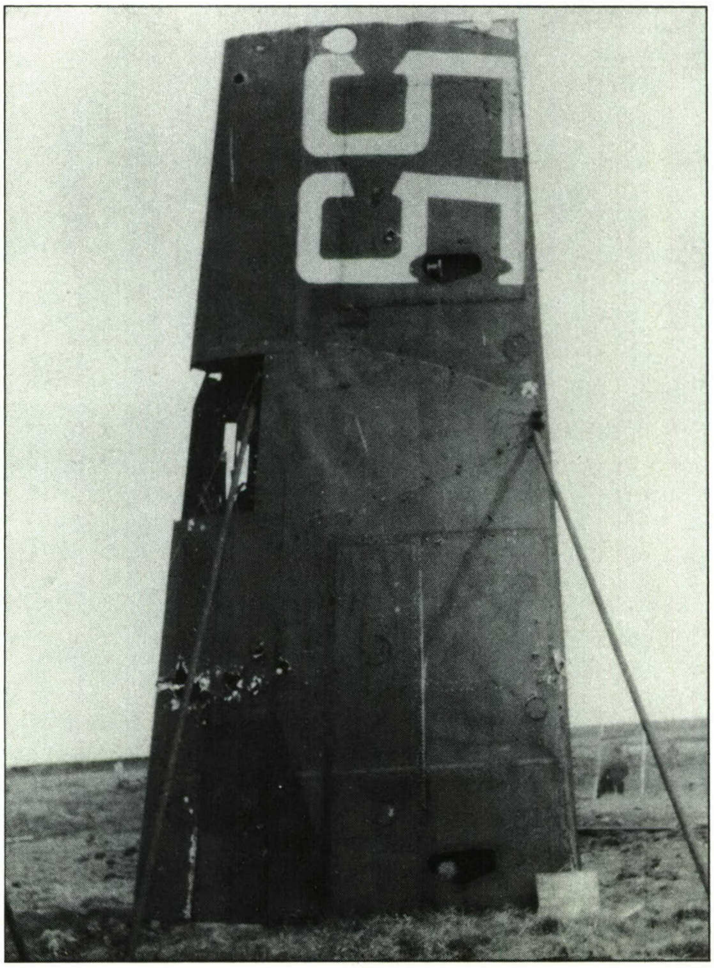


FIG. 14c. ROD EXITS

FIG. 14a, 14b, 14c. LANCASTER AIRCRAFT OUTER WING, TANKS 7/8 ths FILLED WATER. (*Table 2; 7c*)

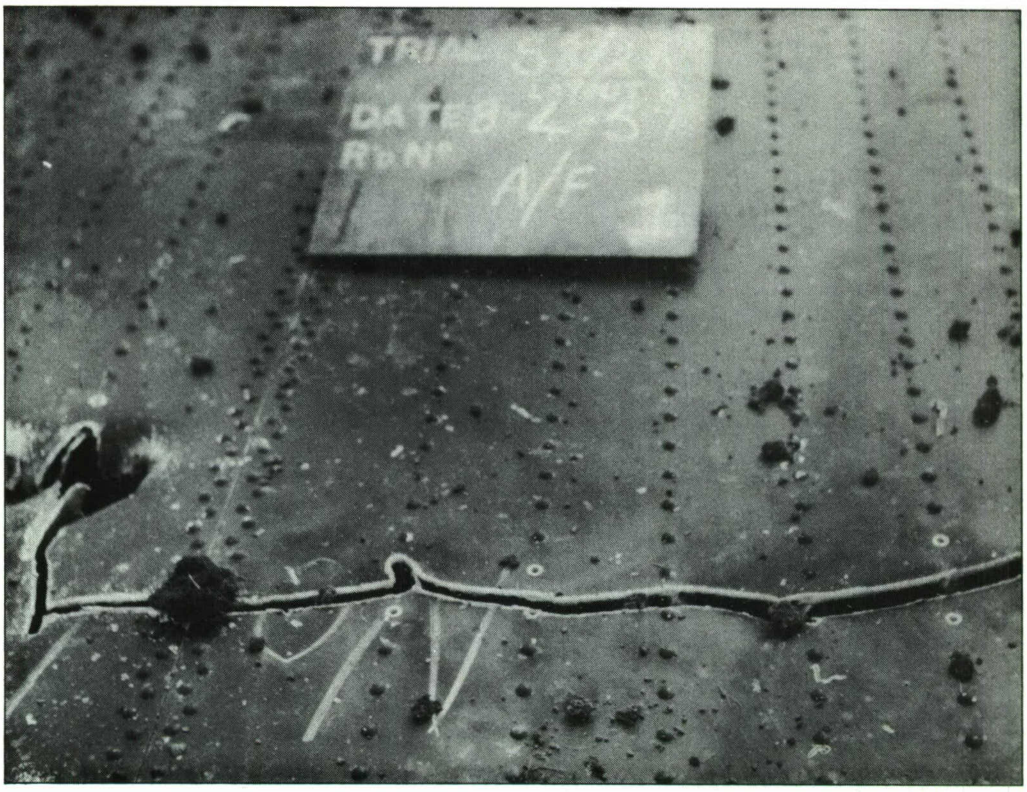


FIG. 15a. ROD ENTRY ON UPPER SURFACE TARGET

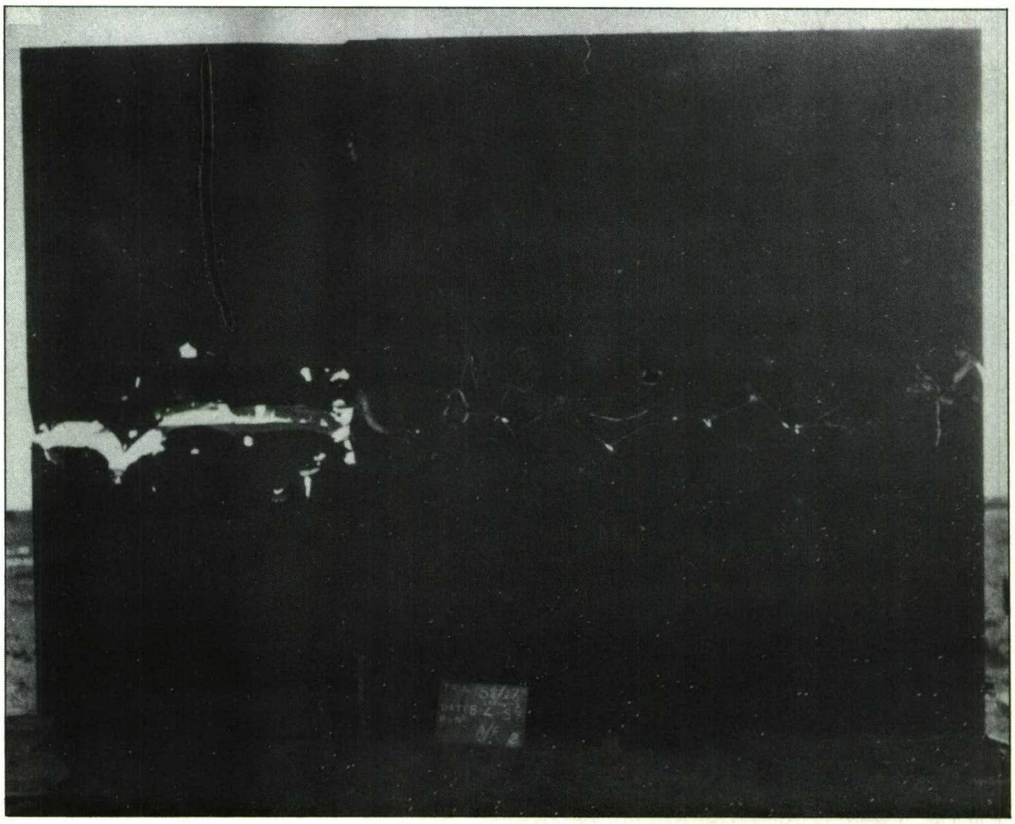


FIG. 15b. ROD ENTRY ON LOWER SURFACE TARGET

FIG. 15a & 15b. REPLICA TARGETS, "R4B" (*Table 2; 8a & 8b*)

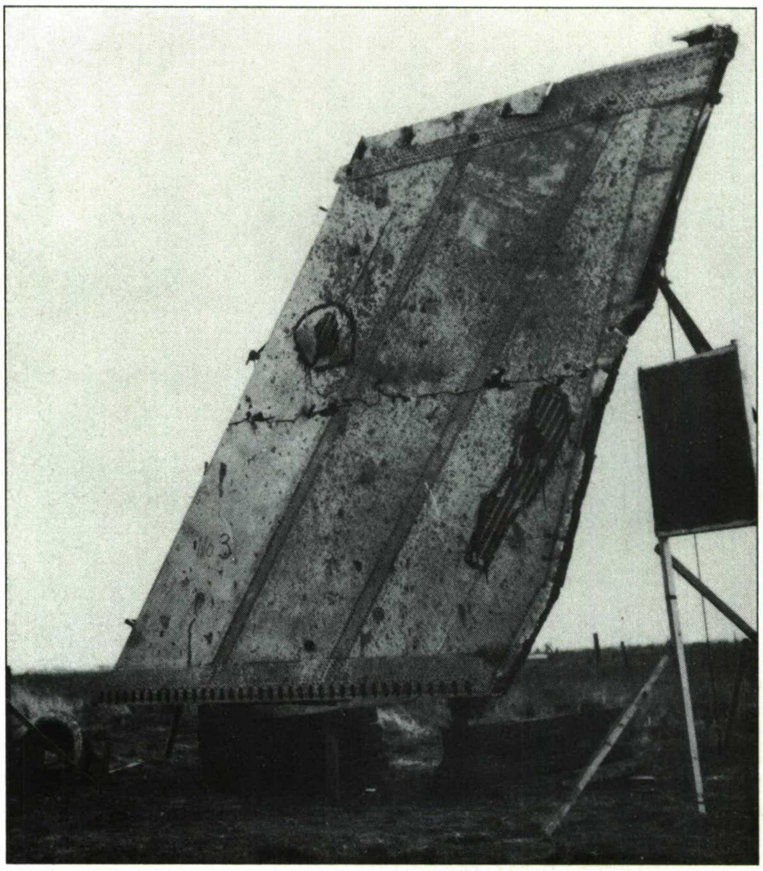


FIG. 16a. ROD ENTRY

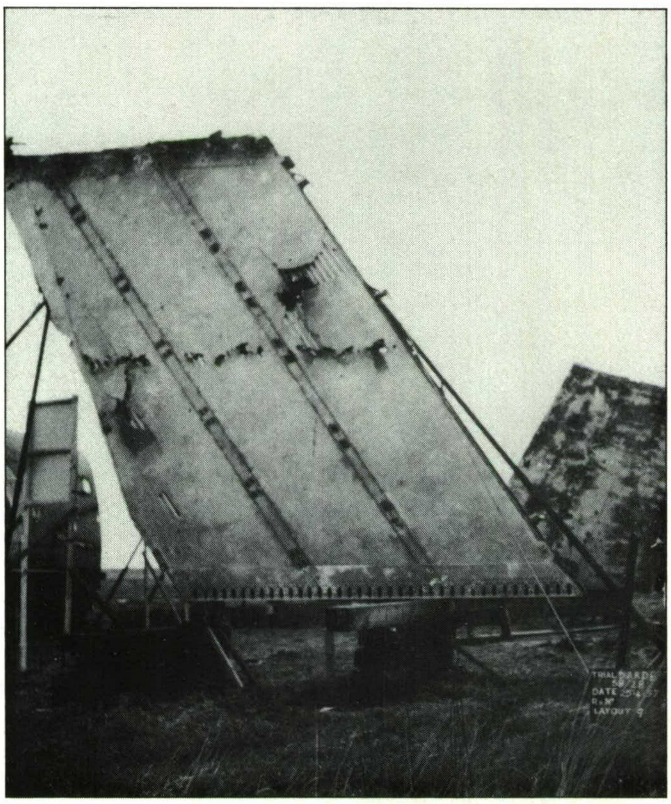


FIG. 16b. ROD EXIT

FIG. 16a & 16b. VICTOR WING. (*Table 2; 9a*)

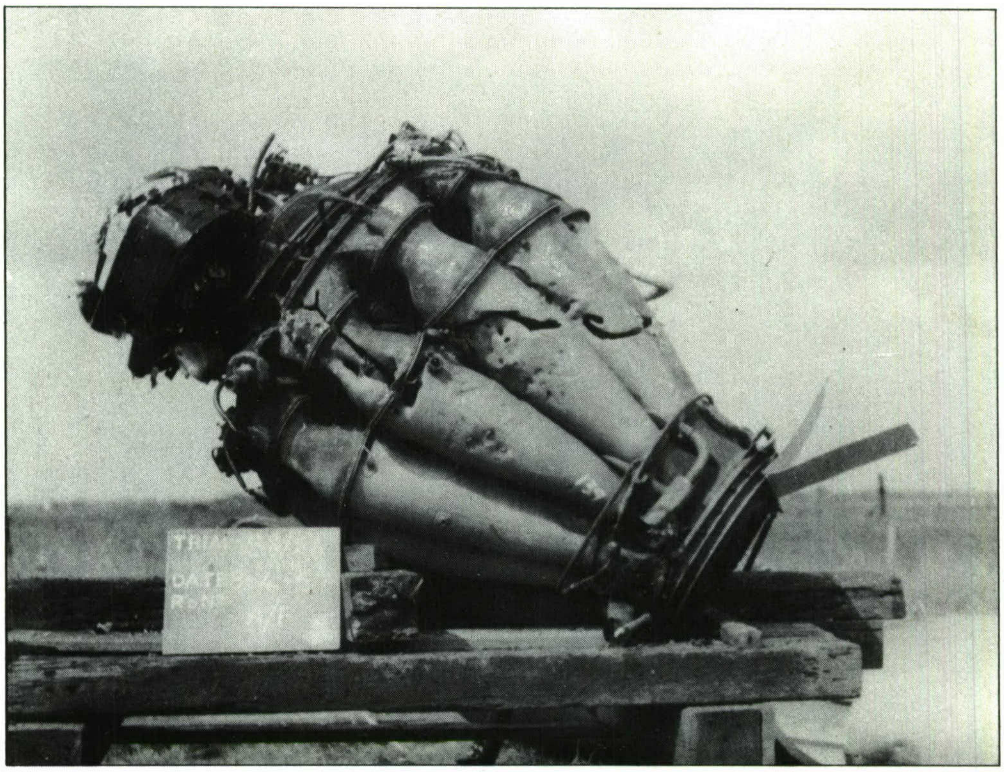


FIG.17a. DERWENT JET ENGINE AFTER FIRING. (*Table 2; 12c*)

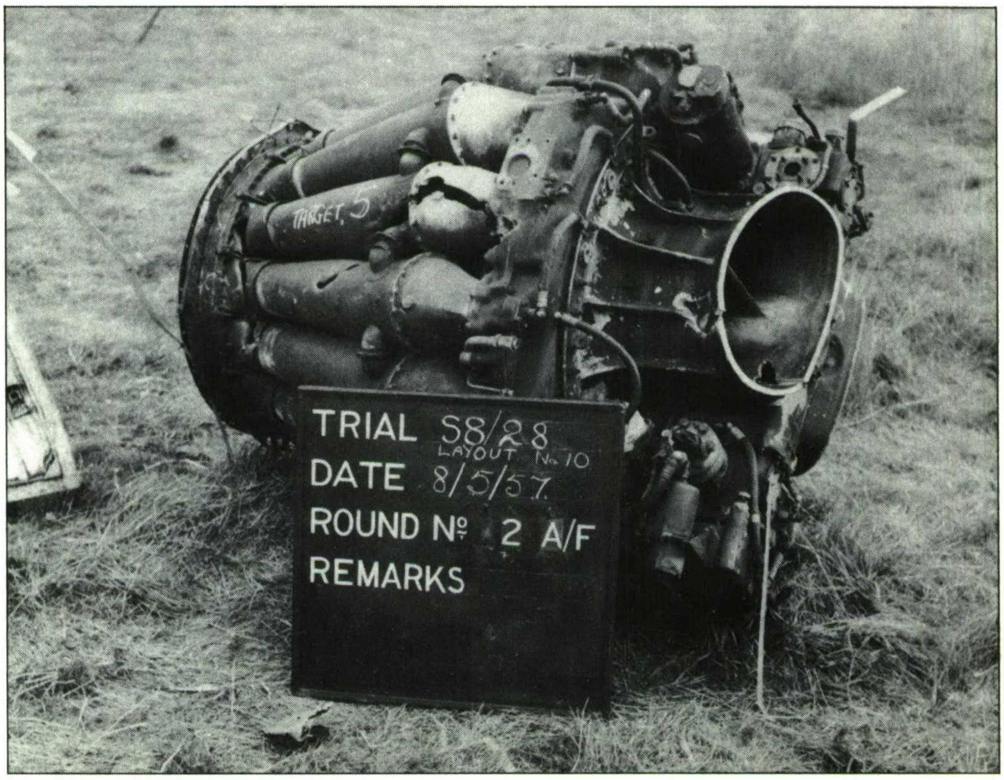


FIG.17b. GOBLIN JET ENGINE AFTER FIRING. (*Table 2; 13c*)

FIG.17a & 17b. JET ENGINES AFTER FIRINGS. (*Table 2; 12c & 13c*)

DETACHABLE ABSTRACT CARDS

These abstract cards are inserted in Reports and Technical Notes for the convenience of Librarians and others who need to maintain an Information Index.

Detached cards are subject to the same Security Regulations as the parent document, and a record of their location should be made on the inside of the back cover of the parent document.

SECRET

Technical Note No. Mech. Eng.261 — 623.565.22:
Royal Aircraft Establishment — 623.562.5

CONTINUOUS-ROD WARHEAD LETHALITY TRIALS AGAINST STATIC AIRCRAFT TARGETS (RODS $\frac{1}{4}$ INCH x $\frac{1}{4}$ INCH CROSS-SECTION). Hancock, D.A. June 1958.

This Note records the results of six static detonations of an experimental type of continuous-rod warhead, with $\frac{1}{4}$ inch square-section rod element, against stationary airframe and turbo-jet engine targets at ground level. An indication of the terminal kill probabilities against various aircraft structures and engines is given.

The warhead is shown to be capable of inflicting lethal damage on most forms of airframe structure, under generally favourable conditions of attack at distances up to about 40 ft from the burst position, and also of causing sufficient damage to put individual jet-engines out of action.

In general, it appears that the $\frac{1}{4}$ inch square-section continuous-rod warhead - as tested - is capable of achieving a reasonable standard of terminal lethality against airframe structures and power plants.

SECRET

DETACHABLE ABSTRACT CARDS

The abstract cards detached from this document are located as follows:-

1 ____________________ 2 ____________________

3 ____________________ 4 ____________________

Signed ______________________ Date _________

CONFIDENTIAL

RECEIVED
8 Dec. 58
Hq. OSW-AO
Dover, N. J.

CONFIDENTIAL

Information Centre
Knowledge Services
[dstl] Porton Down,
Salisbury
Wilts
SP4 0JQ
22060-6218
Tel: 01980-613753
Fax 01980-613970

Defense Technical Information Center (DTIC)
8725 John J. Kingman Road, Suit 0944
Fort Belvoir, VA 22060-6218
U.S.A.

AD#: AD303459

Date of Search: 28 July 2008

Record Summary: AVIA 6/20567
Title: Continous-Rod Warhead Lethality Trials Against Static Aircraft Targets (rods 0.25 inch X 0.25 Inch Cross Section)
Availability Open Document, Open Description, Normal Closure before FOI Act: 30 years
Former reference (Department) Technical Note ME 261
Held by The National Archives, Kew

This document is now available at the National Archives, Kew, Surrey, United Kingdom.

DTIC has checked the National Archives Catalogue website (http://www.nationalarchives.gov.uk) and found the document is available and releasable to the public.

Access to UK public records is governed by statute, namely the Public Records Act, 1958, and the Public Records Act, 1967.
The document has been released under the 30 year rule.
(The vast majority of records selected for permanent preservation are made available to the public when they are 30 years old. This is commonly referred to as the 30 year rule and was established by the Public Records Act of 1967).

This document may be treated as <u>UNLIMITED</u>.